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(54) **Mode field diameter conversion fiber**

Faser mit veränderbarem Modenfelddurchmesser

Fibre avec diamètre du champ modul variable

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Description

The present invention relates to the manufacture of an optical waveguide capable of converting a mode field diameter at a desired portion thereof, such as a mode field diameter conversion fiber and a planar light waveguide device. In particular, the invention relates to a method of manufacturing an optical waveguide, having a doped central core portion made of a light propagating material which has a predetermined refractive index, and a surrounding cladding portion surrounding said light propagating material and having a lower refractive index than said light propagating material, said method comprising the steps of introducing into a core portion a first dopant having a function of increasing the refractive index of said light propagating material and having a first thermal diffusion coefficient to said light propagating material at a predetermined temperature, and a uniformly distributed second dopant having a function of decreasing the refractive index of said light propagating material and having a second thermal diffusion coefficient to said light propagating material at said predetermined temperature, said second thermal diffusion coefficient being larger than the first thermal diffusion coefficient at the predetermined temperature, thereby to form said doped central core portion, the introduction of the dopants resulting in the manufactured optical waveguide having a predetermined mode field diameter. Such a method is disclosed in US-A-4 441 788.

EP-A-0 127 408 and EP-A-0 334 247 disclose a fibre with a fluorine-containing inner cladding and a germanium-doped core.

Electronic Letters, 18th February 1988, Vol. 24. No. 4, pages 245 and 246 "Tapers in Single Mode Optical Fibre by Controlled Core Diffusion" and Journal of Lightwave Technology, Vol. 8, No. 8, August 1990, pages 1151-1161, "Beam Expanding Fiber Using Thermal Diffusion of the Dopant" both teach tapering by heat-treating a doped waveguide core.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a mode field diameter conversion optical element capable of changing the mode field diameter (the spot size of the propagating mode) in a desired portion thereof.

According to the present invention, there is provided a method as initially defined, characterised by subsequently heating the optical waveguide to said predetermined temperature so as to reduce the mode field diameter of said optical waveguide with respect to said predetermined mode field diameter by causing diffusion of the second dopant introduced into said central core portion.

In one form of dopant distribution, the first dopant and the second dopant have substantially uniform concentration distribution in the core portion. In another form of dopant distribution, the second dopant has a substantially uniform concentration distribution in the core portion but the concentration distribution in the core portion of the first dopant is high at a substantially center area and low in a peripheral area so that a refractive index in the periphery of the core is smaller than that of a cladding portion. The concentration distribution of the first dopant in this case is substantially parabolic or stepwise.

By heating the predetermined portion of the optical waveguide, the first and second dopants are thermally diffused from the predetermined portion of the core portion. In this case, since the second thermal diffusion coefficient is larger than the first thermal diffusion coefficient at a predetermined temperature, the second dopant diffuses to a more distant area from the center of the core than the first dopant does. As a result, in both forms of the dopant distribution described above, a difference between a refractive index in the area close to the center of the core and a refractive index of the area distant from the center of the core relatively increases. Consequently, the spot size of the mode is reduced at the predetermined area having thermal processing applied thereto. In the second form of the dopant distribution, the spot size of the mode is reduced by an effect of substantial increase of the core size in which the refractive index is larger than that of the clad by the diffusion of the second dopant.

When the predetermined portion of the other optical waveguide is heated, the first dopant diffuses from the predetermined portion of the core portion to the cladding portion and the second dopant diffuses from the clad to the core portion. Since both diffusions have effects of lowering the differential refractive index Δn between the core portion and the cladding portion, the spot size of the mode is increased at the predetermined portion having the heat treatment applied thereto at a faster speed than that of the prior art.

Here, the differential refractive index Δn between the core portion and the cladding portion means the following.

$$\Delta n = ((n1 \times n1) - (n2 \times n2)) / (2 \times n1 \times n1)$$

$$\simeq (n1 - n2) / n1$$

The n1 is a refractive index of the core portion, and the n2 is a refractive index of the cladding portion.

As a result, the optical waveguide having the spot size of the mode changed at the desired portion is attained. Such an optical waveguide may be used as not only a mere optical transmission line but also an optical device for converting the spot size of the mode at a small loss.

The present invention will become more fully understood from the detailed description given hereinbelow and the accompanying drawings which are given by way

of illustration only, and thus are not to be considered as limiting the present invention.

Further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the scope of the invention will become apparent to those skilled in the art form this detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1A shows a structure of an optical fiber usable in the present invention,
Figs. 1B-1D are drawings for explaining the method of converting a mode field diameter of an optical fiber according to a first embodiment,
Fig. 2 shows a graph of a relation between a core diameter and a refractive index distribution, and a mode field diameter,
Figs. 3A-3D show a manufacturing process of the fiber,
Fig. 4A shows a structure of an optical fiber usable in a second embodiment,
Figs. 4B-4D are drawings for explaining the method of converting a mode field diameter of an optical fiber according to the second embodiment,
Fig. 5 shows a graph of a relation between the core diameter and the refractive index distribution, and the mode field diameter,
Figs. 6A-6D show a manufacturing process of the fiber usable in the second embodiment,
Fig. 7A shows a structure of an optical fiber usable in the third embodiment,
Figs. 7B-7D are drawings for explaining the method of converting a mode field diameter,
Figs. 8A-8D show a manufacturing process of a fiber,
Fig. 9 shows an example of application of the claimed method to an optical waveguide, and
Fig. 10 shows a further example of application of the present invention to an optical waveguide.

DETAILED DESCTIPTION OF THE PREFERRED EMBODIMENTS

The embodiments of the present invention are now briefly explained with reference to the accompanying drawings.

(First Embodiment)

Fig. 1A shows a structure of an optical fiber. The optical fiber has a core to which Ge and F are added at a substantially uniform concentration as shown in Fig. 1A.

A thermal diffusion coefficient of the F is larger than that of the Ge at the temperature of 1600 °C to 2200 °C. That is, the F is diffusing faster than the Ge above 1600 °C.

Figs. 1B-1D schematically show a structure and changes in distributions before and after the heat treatment for converting the mode field diameter. Fig. 1B shows a change in a concentration distribution of the first dopant added to the core, Fig. 1C shows a change in a concentration distribution of the second dopant added to the core, and Fig. 1D shows a change in a refractive index near the core. A graph in Fig. 2 shows relation between the mode field diameter and core diameter, and a difference of refractive indices between the core and the cladding when the distribution of the refractive index in the fiber is stepwise.

The fiber prior to heating shown in Fig. 1A is a single mode fiber and is formed by a known VAD method in a process shown in Figs. 3A-3D. Soot preform for the core made of quartz having germanium (Ge) added thereto as the first dopant (see Fig. 3A) and fluorine (F) is added as the second dopant before it is made transparent (see Fig. 3B). Then, the soot preform for the core is made transparent and elongated to an appropriate outer diameter, and soot for the cladding is formed around it using it as an axis (see Fig. 3C). Then, the soot for the cladding is made transparent to form preform for forming the optical fiber. The preform is drawn under an appropriate condition (see Fig. 3D). In this manner, the optical fiber for the mode field diameter conversion having Ge and F added to the core is formed.

Referring to Fig. 1B to Fig. 1D and Fig. 2, a method and a principle of forming the above optical fiber into the mode field diameter conversion fiber are described. In the following discussion, it is assumed herein that fluorine diffuses sufficiently faster than germanium by heating and after the heating the concentration distribution of fluorine substantially uniformly decreases and the concentration distribution of germanium does not substantially change. The diameter of the core of the optical fiber before the heat treatment is 4μm.

As shown in Fig. 1B, in the core area of the optical fiber before the thermal diffusion, Ge is added in the core area at a substantially uniform concentration. Further, as shown in Fig. 1C, F is also added to the core area at a substantially uniform concentration. It is assumed that a contribution Δ(Ge) of Ge to the differential refractive index is 0.5%, and a contribution Δ(F) of F to the differential refractive index is -0.3%. The heat treatment is applied to a desired portion of the optical fiber to thermally diffuse Ge and F. Ge does not substantially diffuse as shown on the right hand of Fig. 1B but F widely diffuses as shown on the right hand of Fig. 1C and the contribution Δ(F) of F in the core to the differential refractive index changes to -0.2%.

Referring to Fig. 1D, a change in the refractive indices near the core before and after the thermal diffusion is discussed. The optical fiber before the thermal diffu-

sion exhibits a substantially uniform refractive index distribution in the core area as shown by a solid line. A differential refractive index Δ(n) between the core and the cladding is 0.2%. A broken line shows a refractive index distribution due to Ge or F. When heat treatment is applied to the desired portion of the optical fiber to thermally diffuse Ge and F,the core diameter does not substantially change as shown by a solid line on the right hand of the drawing, and the differential refractive index Δ(n) is 0.3%. The change in the mode field diameter for the above changes is discussed with reference to Fig. 2. Before heating, the differential refractive index Δ(n) is 0.2% and the core diameter is 4μm which corresponds to a point A in the graph of Fig. 2, and the mode field diameter is 32μm. After the thermal diffusion by heating, the differential refractive index Δ(n) is 0.3% and the core diameter is 4μm which corresponds to a point A' in the graph of Fig. 2, and the mode field diameter decreases to 14μm.

(Second Embodiment)

Fig. 4A shows a structure of a further optical fiber. The optical fiber has a core to which Ge is added at a substantially radial concentration distribution which is one of graded distributions and F is added at a substantially uniform concentration.

A thermal diffusion coefficient of the F is larger than that of the Ge at the temperature of 1600 °C to 2200 °C. That is, the F is diffusing faster than the Ge above 1600 °C.

Fig. 4B-4D schematically show a structure and changes in distributions before and after the heat treatment for converting the mode field diameter. Fig. 4B shows a change in a concentration distribution of the first dopant added to the core, Fig. 4C shows a change in a concentration distribution of the second dopant added to the core, and Fig. 4D shows a change in the refractive index near the core. A graph of Fig. 5 shows a relation between the mode field diameter and the core diameter, and the differential refractive index between the core and the cladding when the distribution of the refractive index in the fiber is of graded type.

The optical fiber before heating shown in Fig. 4A is a single mode fiber and it is formed by a known VAD method or rod-in-tube method in a precess shown in Figs. 6A-6D. Soot preform for the core made of quartz having germanium (Ge) added thereto as the first dopant is formed (see Fig. 6A), and before it is made transparent, fluorine (F) is added as the second dopant (see Fig. 6B). Then, the soot preform for the core is made transparent and elongated and inserted into a cylindrical cladding preform to form a fiber preform (see Fig. 6C). Then, the fiber preform is drawn under an appropriate condition (see Fig. 6D). In this manner, the optical fiber for the mode field conversion having Ge and F added to the core is formed.

Referring to Fig. 4B to Fig. 4D, a method and a principle of forming the above optical fiber to the mode field diameter conversion fiber are explained. In the following discussion, it is assumed that fluorine diffuse sufficiently faster than germanium, and after heating the concentration distribution of fluorine substantially uniformly decreases and the concentration distribution of germanium does not substantially change. The core diameter of the optical fiber before heat treatment is 10μm.

As shown in Fig. 4B, in the core area of the optical fiber before the thermal diffusion, Ge is added at a substantially radial concentration distribution which is one of graded distributions and as shown in Fig. 4C, F is added at a substantially uniform concentration. It is assumed that the contribution Δ(Ge) of Ge to the differential refractive index is 0.4% and the contribution Δ(F) of F to the differential refractive index is -0.2%. Heat treatment is applied to a desired portion of the optical fiber having the structure described above to thermally diffuse Ge and F. Ge does not substantially diffuse as shown on the right hand of Fig. 1B but F widely diffuses as shown on the right hand of Fig. 4C so that the contribution Δ(F) of F to the differential refractive index in the core area changes to -0.12%.

Referring to Fig. 4D, the change in the refractive indices near the core before and after the thermal diffusion is discussed. The optical fiber before the thermal diffusion exhibits a substantially parabolic refractive index distribution in the core area as shown by a solid line. In the core periphery, the contribution by F to the increase of the refractive index is larger than the contribution by Ge to the increase of the refractive index and the diameter of the substantial core area having a larger refractive index than that of the cladding is smaller than the core diameter formed in the process of Figs. 6A-6D. A broken line shows a refractive index distribution due to Ge or F. When heat treatment is applied to the desired portion of the optical fiber to thermally diffuse Ge and F, the refractive index of the core area increases and the core diameter substantially increases as shown on the right hand of the drawing. The change of the mode field diameter for the above changes is discussed with reference to Fig. 5. Before heating, the differential refractive index contribution Δ(Ge) of Ge is 0.4%, the differential refractive index contribution Δ(F) of F is -0.2%, and the substantial core diameter is no larger than 10μm. From the coordinate of a point B on the graph of Fig. 5, the mode field diameter is at least approximately 40μm. After the thermal diffusion by heating, the differential refractive index contribution Δ(Ge) of Ge is 0.4%, the differential refractive index contribution Δ(F) of F is -0.12% and the substantial core diameter is approximately 10μm, which corresponds to a point B' on the graph of Fig. 5, and the mode field diameter is reduced to approximately 11μm. In the present embodiment, the increase of the differential refractive index between the core and the cladding of the first embodiment as well as the increase of the substantial core diameter contribute to the reduction of the mode field diameter by heating

so that efficient reduction of the mode field diameter is attained.

(Third Embodiment)

Fig. 7A shows a structure of a third optical fiber. The optical fiber has a core area to which Ge is added at a substantially stepwise (two steps) concentration distribution and F is also added at a substantially uniform concentration.

A thermal diffusion coefficient of the F is larger than that of the Ge at the temperature of 1600 °C to 2200 °C. That is, the F is diffusing faster than the Ge above 1600 °C.

Figs. 7B-7D schematically show a structure and changes in distributions before and after the heat treatment for converting the mode field diameter. Fig. 7B shows a change in the concentration distribution of the first dopant added to the core, Fig. 7C shows a change in the concentration distribution of the second dopant added to the core, and Fig. 7D shows a change in the refractive index near the core.

The fiber prior to heating shown in Fig. 7A is a single mode fiber and is formed by a known VAD method or rod-in-tube method in a process shown in Figs. 8A-8D. Soot preform for the core made of quartz having germanium (Ge) added thereto as the first dopant (see Fig. 8A) and fluorine (F) is added as the second dopant before it is made transparent (see Fig. 8B). Then, the soot preform for the core is made transparent and expanded and inserted into a cylindrical cladding preform to form a fiber preform (see Fig. 8C). Then, the fiber preform is drawn under an appropriate condition (see Fig. 8D). In this manner, the optical fiber for the mode field diameter conversion having Ge and F added to the core is formed.

Referring to Fig. 7B to Fig. 7D, a method and a principle of forming the above optical fiber into the mode field diameter conversion fiber are described. In the following discussion, it is assumed herein that fluorine diffused sufficiently faster than germanium by heating and after the heating the concentration distribution of fluorine substantially uniformly decreases and the concentration distribution of germanium does not substantially change.

As shown in Fig. 7B, in the core area of the optical fiber before the thermal diffusion, Ge is added in the core area at a substantially stepwise (two steps) concentration distribution and as shown in Fig. 7C, F is also added to the core area at a substantially uniform concentration. The heat treatment is applied to a desired portion of the optical fiber to thermally diffuse Ge and F. Ge does not substantially diffuse as shown on the right hand of Fig. 7B but F widely diffuses as shown on the right hand of Fig. 7C.

Referring to Fig. 7D, a change in the refractive indices near the core before and after the thermal diffusion is discussed. The optical fiber before the thermal diffusion exhibits a substantially stepwise refractive index distribution in the core area as shown by a solid line. The contribution to the decrease of the refractive index by F is larger than the contribution to the increase of the refractive index by Ge and the substantial core diameter in which the refractive index is larger than that of the cladding is smaller than the core diameter formed in the process of Figs. 6A-6D. A broken line shows a refractive index distribution due to Ge or F. When heat treatment is applied to the desired portion of the optical fiber to thermally diffuse Ge and F, the refractive index of the core increases and the substantial core diameter increases. In the present embodiment, since the increase of the differential refractive index between the core and the cladding of the first embodiment as well as the increase of the substantial core diameter contribute to the decrease of the mode field diameter by heating, so they do in the second embodiment, efficient reduction of the mode field diameter is attained.

The optical waveguide capable of changing a spot size of a propagating mode may be used in various applications which require to narrow a spot size of a propagating mode. For example, as shown in Fig. 9, an optical device 2 such as a filter, an isolator and so on, can be inserted between fibers 3 for optical communication which has a small mode field diameter, through an optical waveguide 1 of the present invention, resulting in no significant loss increase. That is, one end of the optical waveguide 1 having a large spot size 16 of a propagating mode area optically connected to the optical device 2 having a large spot size of a propagating mode decreases the diffraction loss due to the insertion of the optical device 2, and the other end of the optical waveguide having a narrowed spot size 1a is optically connected to the optical fiber 3 having a small mode field diameter. The narrowed spot size portion 1a of the optical waveguide 1 is formed by heating the portion 1a at the predetermined temperature, such as 1600 °C to 2200 °C Further, the optical fiber 3 and the optical waveguide 1 also may be fused at the predetermined temperature to be connected to each other. Additionally, an interface between the optical device 2 such as a filter and the optical waveguide may be slightly inclined with respect to a light transmission direction of them. The core diameter of the waveguide for the above embodiments is desired to be smaller than one in which minimizes a spot size of a propagating mode, because the change of the spot size by thermal diffusion can be increased as shown in Figs. 2 and 5.

Further, the above embodiments are directed to an optical fiber, but the present invention can be applied to a planar optical waveguide as shown in Fig. 13. In the case of the planar optical waveguide, the light guide path may be formed by flame hydrolisys deposition or plasma induced chamical vapor deposition. In Fig. 10, a core 10a is formed as a rectangular and a spot size of a propagating mode is narrowed by heating a portion 10b.

While the present invention has been explained

with reference to the embodiments, various modifications thereof may be made. For example, the optical waveguide capable of change a spot size of the mode of the present invention may be formed by various methods including MCVD method, OVD method and double crucible method. The first and second dopants are not limited to Ge and F but various other dopants may be used. The differential refractive index between the core portion and the cladding portion may be set to a desired value depending on the setting condition of the thermal diffusion temperature. Not only the single mode fiber but also a multi-mode type optical waveguide attains the same effects.

In accordance with the method according to the present invention, the first dopant which increases the refractive index is added to the core and the second dopant which decreases the refractive index and has a larger thermal diffusion coefficient than that of the first dopant at a predetermined temperature is added to the core and the clad with the distribution. Accordingly, by heating the predetermined portion at the predetermined temperature, the difference between the refractive index in the area close to the center of the core and the refractive index distant from the center of the core relatively increases or decreases and the mode field diameter increases or decreases in a short time at the predetermined portion which has been heat-treated. When the optical waveguide having a spot size of a propagating mode which decreases by heating is used, the core diameter is set to be smaller than one which minimizes the spot size in the propagating mode and the dopant distribution is set to increase the substantial core diameter by heating so that the spot size is efficiently reduced. As a result, the optical waveguide having the spot size of a propagating mode changed at the desired point is formed. With such an optical waveguide, an optical waveguide having a larger or smaller spot size can be connected to an optical part having a smaller or larger mode field diameter with a small loss.

From the invention thus described, it will be obvious that the invention may be varied in many ways. Such variations are not to be regarded as a departure from the scope of the invention as defined in the attached claims.

Claims

1. A method of manufacturing an optical waveguide, having a doped central core portion made of a light propagating material which has a predetermined refractive index, and a surrounding cladding portion surrounding said light propagating material and having a lower refractive index than said light propagating material, said method comprising the steps of:-

   introducing into a core portion (i) a first dopant having a function of increasing the refractive index (n) of said light propagating material and having a first thermal diffusion coefficient to said light propagating material at a predetermined temperature, and (ii) a uniformly distributed second dopant having a function of decreasing the refractive index (n) of said light propagating material and having a second thermal diffusion coefficient to said light propagating material at said predetermined temperature, said second thermal diffusion coefficient being larger than the first thermal diffusion coefficient at the predetermined temperature, thereby to form said doped central core portion; the introduction of the dopants resulting in the manufactured optical waveguide having a predetermined mode field diameter (MFD);

   characterised by subsequently heating the optical waveguide to said predetermined temperature so as to reduce the mode field diameter (MFD) of said optical waveguide with respect to said predetermined mode field diameter by causing diffusion of the second dopant introduced into said central core portion.

2. A method according to claim 1, wherein the concentration distribution in said central core portion of said first dopant is substantially uniform.

3. A method according to claim 1, wherein the concentration distribution in said central core portion of said first dopant is substantially high at a center and low at a periphery.

4. A method according to claim 3, wherein the concentration distribution in said central core portion of said first dopant is substantially parabolic.

5. A method according to claim 3, wherein the concentration distribution in said central core portion of said first dopant is substantially stepwise.

6. A method according to any preceding claim, wherein said optical waveguide is an optical fiber.

7. A method according to any preceding claim, wherein said optical waveguide is a planar light waveguide.

8. A method according to any preceding claim, wherein the predetermined temperature is about 1600°C to 2200°C.

9. A method for converting a mode field diameter of an optical waveguide having a doped central core portion made of a light propagating material which has a predetermined refractive index, and a sur-

rounding cladding portion surrounding said light propagating material and having a lower refractive index than said light propagating material, said method comprising the steps of:-

introducing into a core portion (i) a first dopant having a function of increasing the refractive index (n) of said light propagating material and having a first thermal diffusion coefficient to said light propagating material at a predetermined temperature, and (ii) a uniformly distributed second dopant having a function of decreasing the refractive index (n) of said light propagating material and having a second thermal diffusion coefficient to said light propagating material at said predetermined temperature, said second thermal diffusion coefficient being larger than the first thermal diffusion coefficient at the predetermined temperature, thereby to form said doped central core portion; the introduction of the dopants resulting in the manufactured optical waveguide having a predetermined mode field diameter (MFD) ;

characterised by:
heating one end (1a) of said optical waveguide at said predetermined temperature, said one end of said optical waveguide being optically connected to an optical fiber; to reduce the mode field diameter of said waveguide at said one end of said optical waveguide.

Patentansprüche

1. Verfahren zur Herstellung eines optischen Wellenleiters, welcher einen dotierten Zentralkernabschnitt hat,
welcher aus einem Lichtausbreitungsmaterial besteht, das einen vorbestimmten Brechungsindex hat, und einen umgebenden Hüllabschnitt, welcher das Lichtausbreitungsmaterial umgibt und einen niedrigeren Brechungsindex hat als das Lichtausbreitungsmaterial, wobei das Verfahren die Schritte umfaßt:

   Einbringung, in einen Kernabschnitt, (i) eines ersten Dotierstoffs, welcher eine Funktion der Erhöhung des Brechungsindex (n) des Lichtausbreitungsmaterials hat und einen ersten thermischen Diffusionskoeffizienten zu dem Lichtausbreitungsmaterial bei einer vorbestimmten Temperatur hat, und (ii) eines gleichmäßig verteilten zweiten Dotierstoffs, welcher eine Funktion der Verringerung des Brechungsindex (n) des Lichtausbreitungsmaterials hat und einen zweiten thermischen Diffusionskoeffizienten zu dem Lichtausbreitungsmaterial bei der vorbestimmten Temperatur hat, wobei der zweite thermische Diffusionskoeffizient größer ist als der erste thermische Diffusionskoeffizient bei der vorbestimmten Temperatur, um dadurch den dotierten Zentralkernabschnitt zu bilden;

   wobei die Einbringung der Dotierstoffe dazu führt, daß die hergestellten optischen Wellenleiter einen vorbestimmten Modenfelddurchmesser (MFD) haben;

   gekennzeichnet durch die spätere Erwärmung des optischen Wellenleiters auf die vorbestimmte Temperatur, um so den Modenfelddurchmesser (MFD) des optischen Wellenleiters bezüglich des vorbestimmten Modenfelddurchmessers zu verringern, indem eine Diffusion des in den zentralen Kernabschnitt eingebrachten zweiten Dotierstoffs bewirkt wird.

2. Verfahren nach Anspruch 1, wobei die Konzentrationsverteilung in dem zentralen Kernabschnitt des ersten Dotierstoffs im wesentlichen gleichmäßig ist.

3. Verfahren nach Anspruch 1, wobei die Konzentrationsverteilung in dem zentralen Kernabschnitt des ersten Dotierstoffs im wesentlichen hoch in der Mitte und tief an der Peripherie ist.

4. Verfahren nach Anspruch 3, wobei die Konzentrationsverteilung in dem zentralen Kernabschnitt des ersten Dotierstoffs im wesentlichen parabolisch ist.

5. Verfahren nach Anspruch 3, wobei die Konzentrationsverteilung in dem zentralen Kernabschnitt des ersten Dotierstoffs im wesentlichen stufenförmig ist.

6. Verfahren nach einem der vorhergehenden Ansprüche, wobei der optische Wellenleiter eine optische Faser ist.

7. Verfahren nach einem der vorhergehenden Ansprüche, wobei der optische Wellenleiter ein planarer Lichtwellenleiter ist.

8. Verfahren nach einem der vorhergehenden Ansprüche, wobei die vorbestimmte Temperatur ungefähr 1600°C bis 2200°C ist.

9. Verfahren zur Umwandlung eines Modenfelddurchmessers eines optischen Wellenleiters, welcher einen dotierten Zentralkernabschnitt hat, der aus einem Lichtausbreitungsmaterial besteht, das einen vorbestimmten Brechungsindex hat, und einem umgebenden Hüllabschnitt, der das Lichtausbreitungsmaterial umgibt und einen niedrigeren Bre-

chungsindex als das Lichtausbreitungsmaterial hat, wobei das Verfahren die Schritte umfaßt:

Einbringung, in einen Kernabschnitt, (i) eines ersten Dotierstoffs, welcher eine Funktion der Erhöhung des Brechungsindex (n) des Lichtausbreitungsmaterials hat und einen ersten thermischen Diffusionskoeffizienten zu dem Lichtausbreitungsmaterial bei einer vorbestimmten Temperatur hat, und (ii) eines gleichmäßig verteilten zweiten Dotierstoffs, welcher eine Funktion der Verringerung des Brechungsindex (n) des Lichtausbreitungsmaterials hat, und einen zweiten thermischen Diffusionskoeffizienten zu dem Ausbreitungsmaterial bei der vorbestimmten Temperatur hat, wobei der zweite thermische Diffusionskoeffizient größer ist als der erste thermische Diffusionskoeffizient bei der vorbestimmten Temperatur, um dadurch den dotierten Zentralkernabschnitt zu bilden;

wobei die Einbringung der Dotierstoffe dazu führt, daß der hergestellte optische Wellenleiter einen vorbestimmten Modenfelddurchmesser (MFD) hat,

gekennzeichnet durch:
Erwärmung eines Endes (1a) des optischen Wellenleiters bei der vorbestimmten Temperatur, wobei das eine Ende des optischen Wellenleiters mit einer optischen Faser optisch verbunden ist; um den Modenfelddurchmesser des Wellenleiters an dem einen Ende des optischen Wellenleiters zu verringern.

Revendications

1. Procédé de fabrication d'un guide d'ondes optiques ayant une portion de coeur centrale dopée, faite en un matériau propageant la lumière qui a un indice de réfraction prédéterminé, et un matériau de gaine entourant ledit matériau propageant la lumière ayant un indice de réfraction inférieur à celui dudit matériau propageant la lumière, ledit procédé comprenant les étapes consistant à :

   introduire dans une portion de coeur (i) un premier dopant ayant pour fonction d'augmenter l'indice de réfraction (n) dudit matériau propageant la lumière, et ayant un premier coefficient de diffusion thermique dans ledit matériau propageant la lumière à une température prédéterminée, et (ii) un second dopant réparti de manière uniforme ayant comme fonction de diminuer l'indice de réfraction (n) dudit matériau propageant la lumière, et ayant un second coefficient de diffusion thermique dans ledit matériau propageant la lumière à ladite température prédéterminée, ledit second coefficient de diffusion thermique étant plus élevé que le premier coefficient de diffusion thermique à la température prédéterminée, pour former ainsi ladite portion de coeur centrale dopée;
   l'introduction des dopants ayant pour résultat que les guides d'ondes optiques fabriqués ont un diamètre du champ modal (MFD) prédéterminé;

   caractérisé par un chauffage subséquent du guide d'onde optique à ladite température prédéterminée, de manière à réduire le diamètre du champ modal dudit guide optique par rapport audit diamètre du champ modal prédéterminé, en provoquant la diffusion du second dopant introduit dans ladite portion de coeur centrale.

2. Procédé selon la revendication 1, dans lequel la répartition de la concentration dans ladite portion de coeur centrale dudit premier dopant est sensiblement uniforme.

3. Procédé selon la revendication 1, dans lequel la répartition de la concentration dans ladite portion de coeur centrale dudit premier dopant est sensiblement élevée au centre, et basse à la périphérie.

4. Procédé selon la revendication 3, dans lequel la répartition de la concentration dans ladite portion de coeur centrale dudit premier dopant est sensiblement parabolique.

5. Procédé selon la revendication 3, dans lequel la répartition de la concentration dans ladite portion de coeur centrale dudit premier dopant est essentiellement avec des paliers.

6. Procédé selon l'une quelconque des revendications précédentes, dans lequel ledit guide d'onde optique est une fibre optique.

7. Procédé selon l'une quelconque des revendications précédentes, dans lequel ledit guide optique est un guide d'onde lumineuses plan.

8. Procédé selon l'une quelconque des revendications précédentes, dans lequel la température prédéterminée est d'environ 1600 °C à 2200 °C.

9. Procédé pour convertir un diamètre de champ modal d'un guide d'ondes optiques ayant une portion de coeur centrale dopée, faite en un matériau propageant la lumière qui a un indice de réfraction prédéterminé, et un matériau de gaine entourant ledit matériau propageant la lumière ayant un indice de

réfraction inférieur à celui du matériau propageant la lumière, ledit procédé comprenant les étapes consistant à :

introduire dans une portion de coeur (i) un premier dopant ayant pour fonction d'augmenter l'indice de réfraction (n) dudit matériau propageant la lumière, et ayant un premier coefficient de diffusion thermique dans ledit matériau propageant la lumière à une température prédéterminée, et (ii) un second dopant réparti de manière uniforme ayant comme fonction de diminuer l'indice de réfraction (n) dudit matériau propageant la lumière, et ayant un second coefficient de diffusion thermique dans ledit matériau propageant la lumière à ladite température prédéterminée, ledit second coefficient de diffusion thermique étant plus élevé que le premier coefficient de diffusion thermique à la température prédéterminée, pour former ainsi ladite portion de coeur centrale dopée;
l'introduction des dopants ayant pour résultat que les guides d'ondes optiques fabriqués ont un diamètre du champ modal prédéterminé;

caractérisé par :
un chauffage d'une extrémité (la) dudit guide optique à ladite température prédéterminée, ladite extrémité dudit guide d'onde optique étant connectée optiquement à une fibre optique; pour diminuer le diamètre de champ modal dudit guide d'onde à ladite extrémité dudit guide d'onde optique.

Fig. 1A

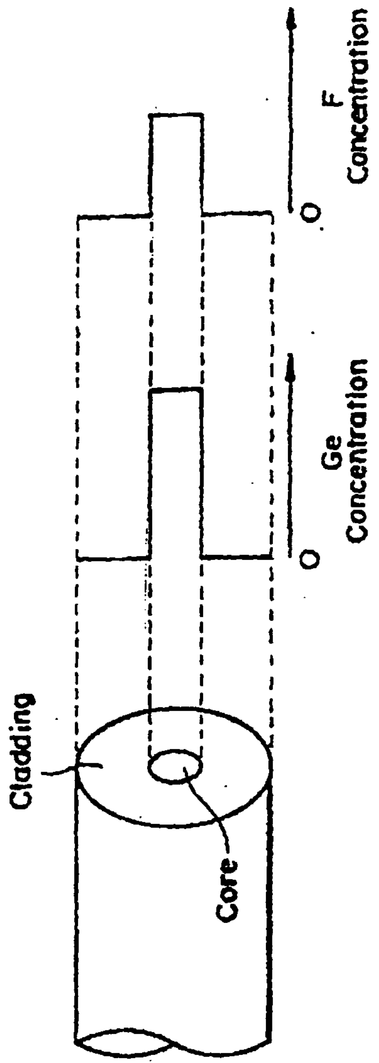


Fig. 1B

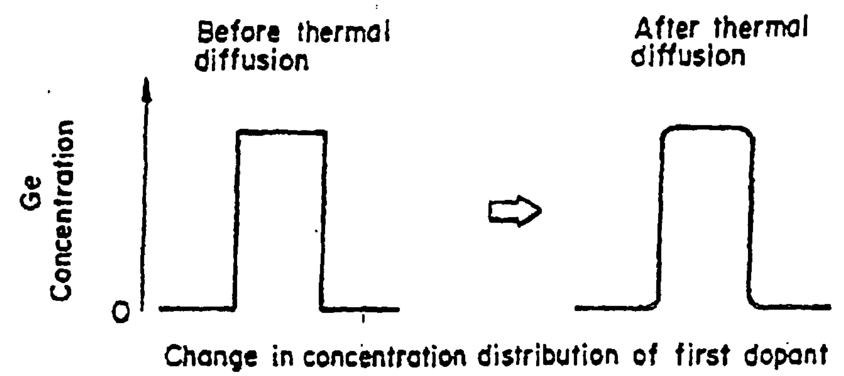


Fig. 1C

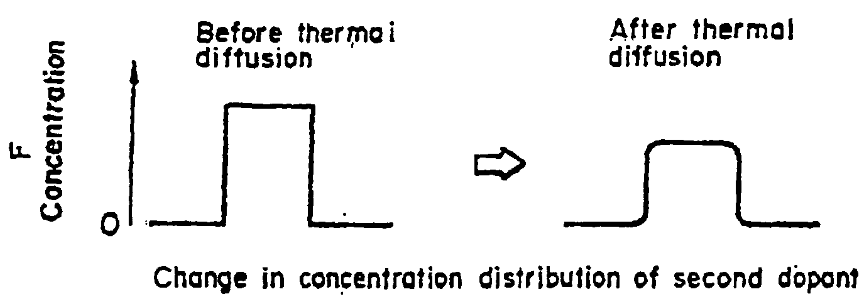


Fig. 1D

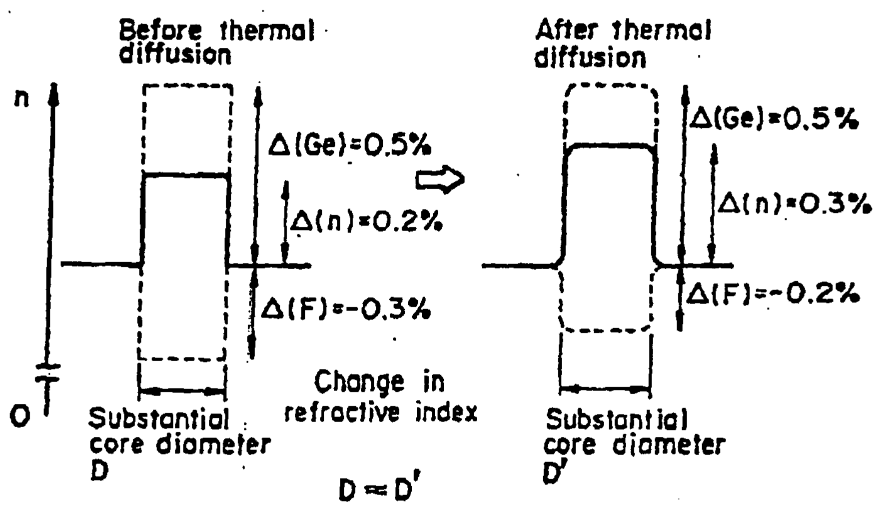
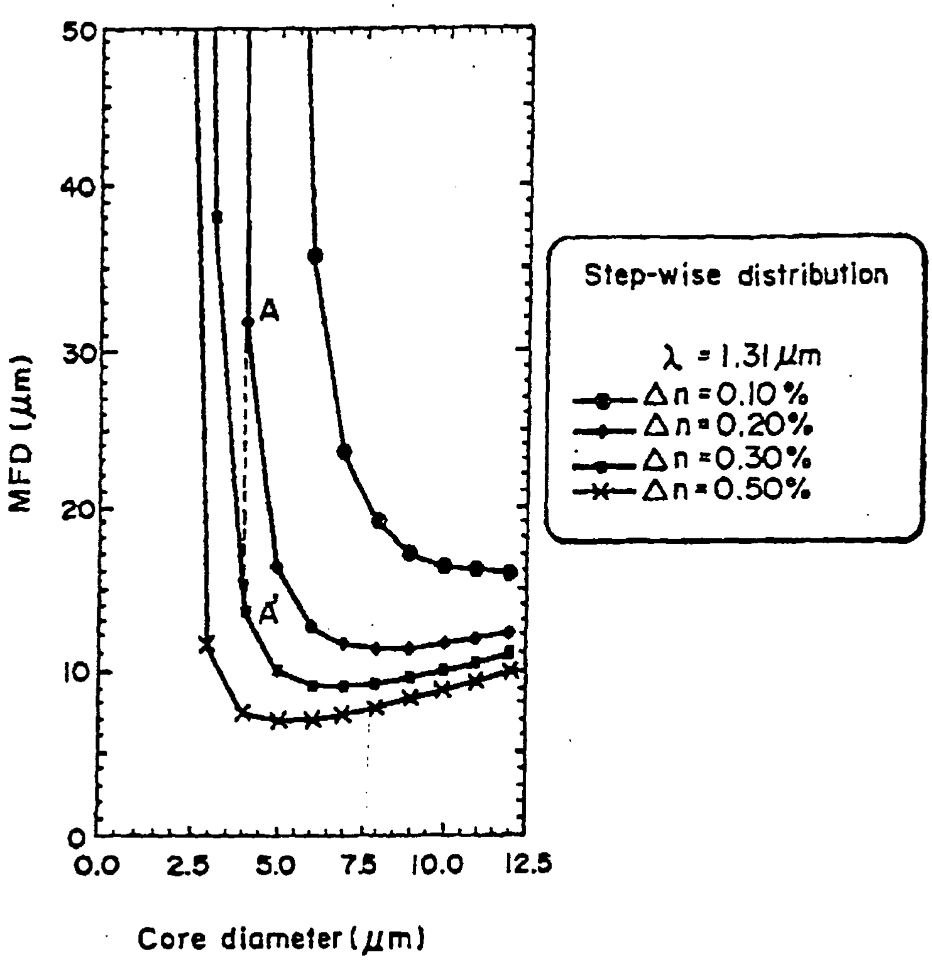


Fig. 2


50
40
30
20
10
0
MFD (μm)
0.0
2.5
5.0
7.5
10.0
12.5
Core diameter (μm)
A
A'
Step-wise distribution
λ = 1.31 μm
Δn = 0.10 %
Δn = 0.20%
Δn = 0.30%
Δn = 0.50%

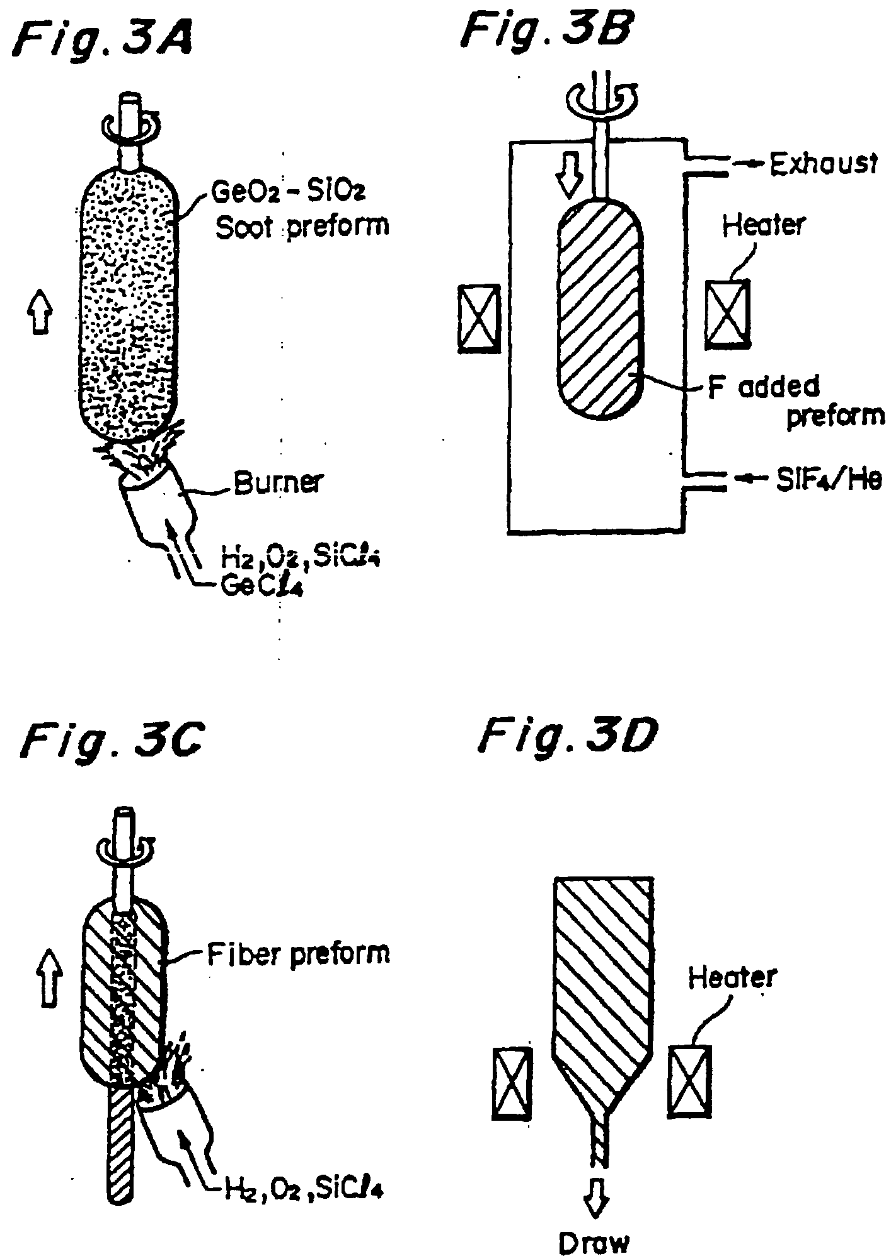


Fig. 3A
GeO2 - SiO2
Soot preform
Burner
H2, O2, SiCl4
GeCl4
Fig. 3B
Exhaust
Heater
F added
preform
SiF4/He
Fig. 3C
Fiber preform
H2, O2, SiCl4
Fig. 3D
Heater
Draw

Fig.4A

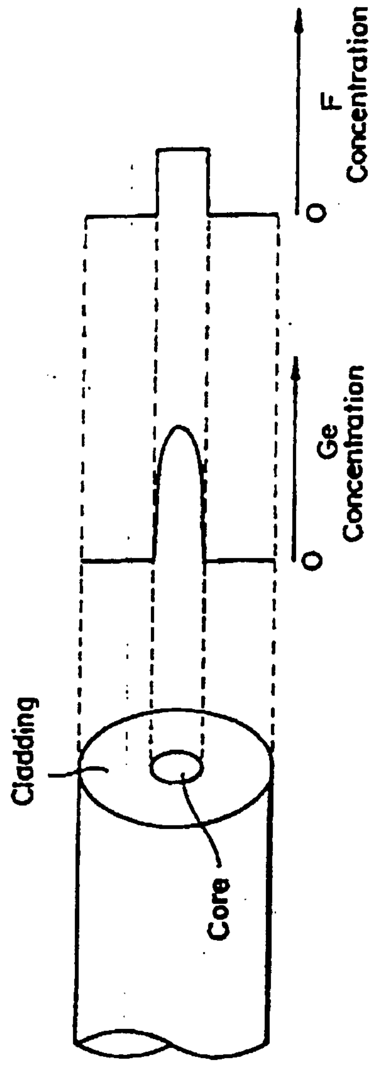
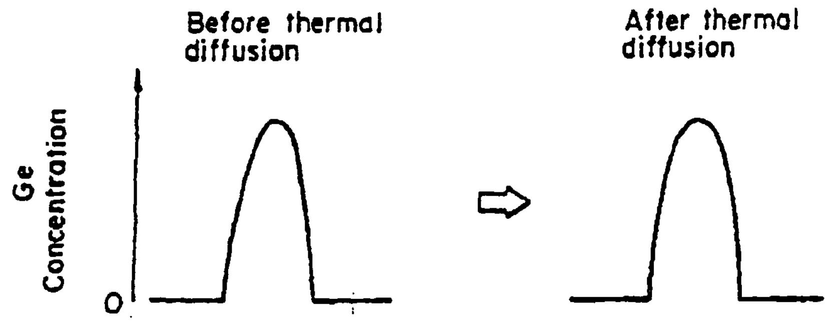
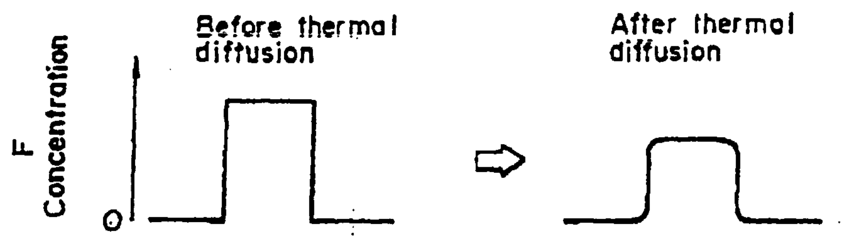


Fig.4B



Change in concentration distribution of first dopant

Fig.4C



Change in concentration distribution of second dopant

Fig.4D

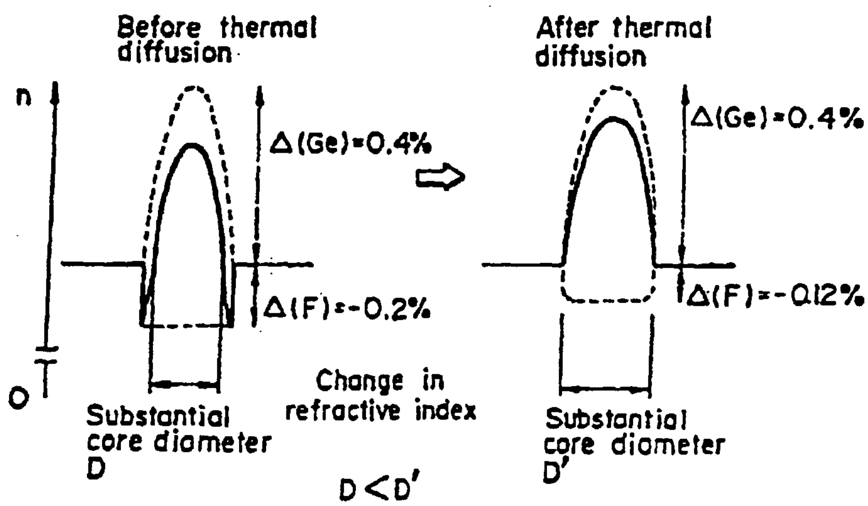


Fig. 5

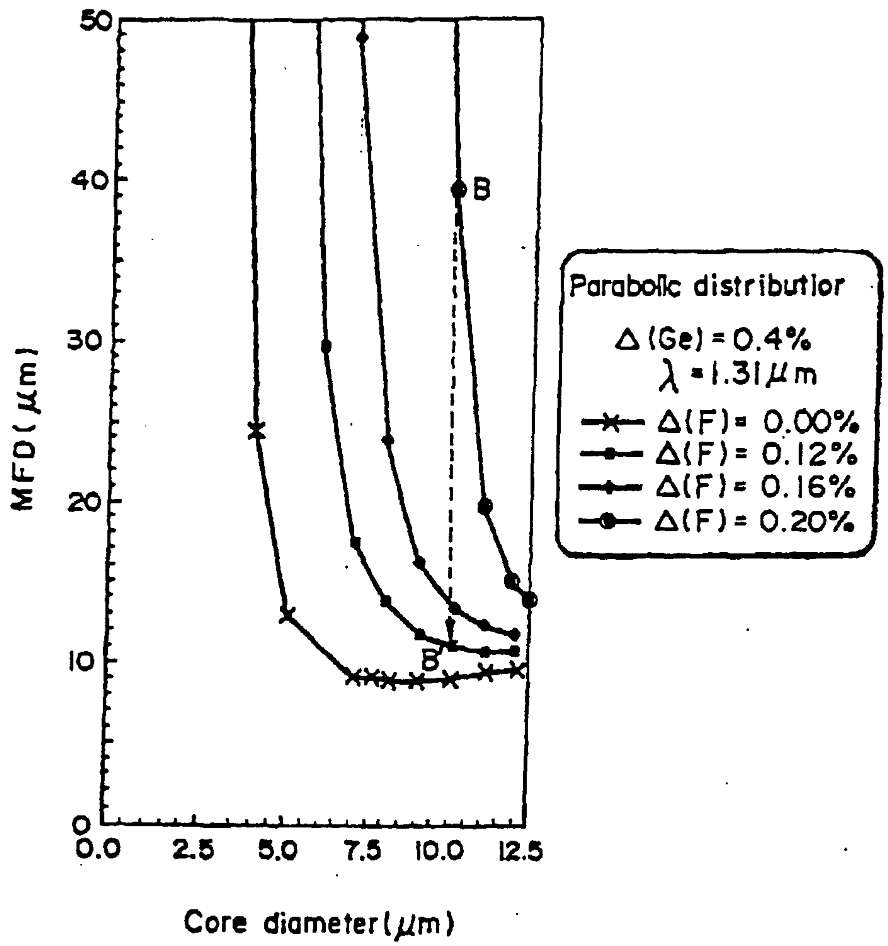

50
40
30
20
10
0
MFD (μm)
0.0
2.5
5.0
7.5
10.0
12.5
Core diameter (μm)
B
B'
Parabolic distributior
Δ (Ge) = 0.4%
λ = 1.31 μm
Δ(F) = 0.00%
Δ(F) = 0.12%
Δ(F) = 0.16%
Δ(F) = 0.20%

Fig. 6A

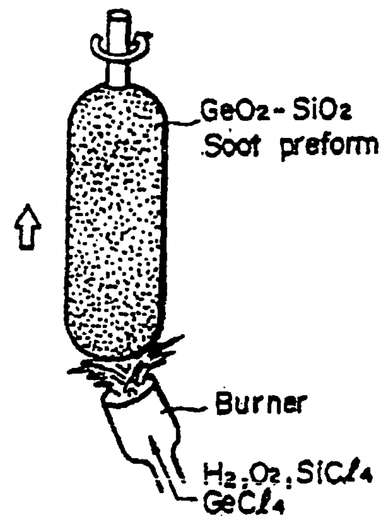


Fig. 6B

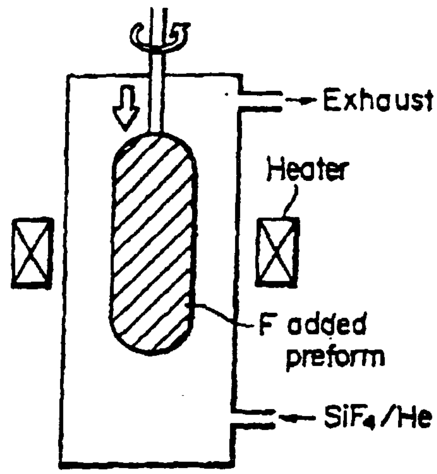


Fig. 6C

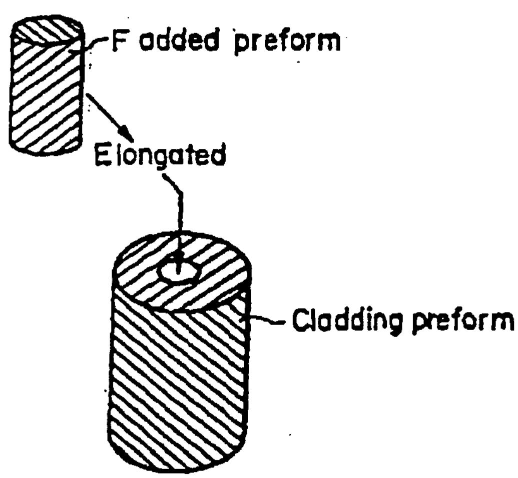


Fig. 6D

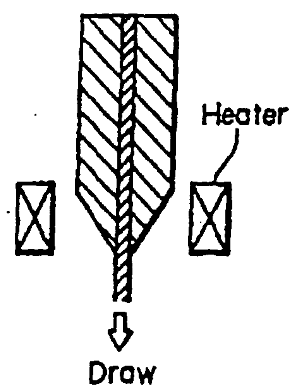


Fig. 7A

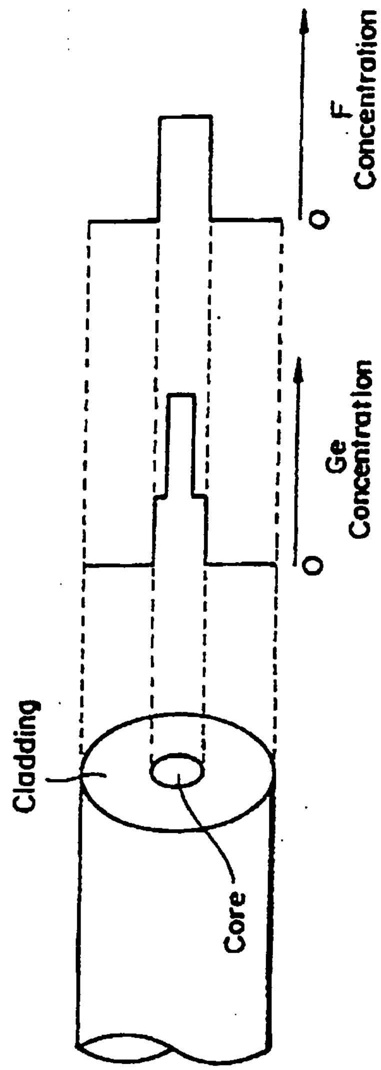


Fig.7B

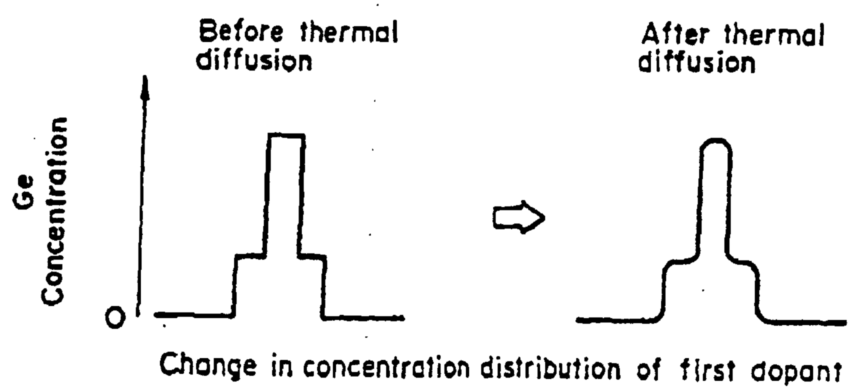


Fig.7C

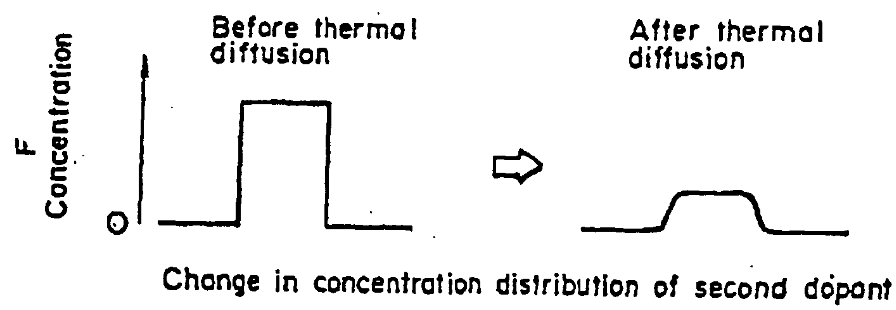


Fig.7D

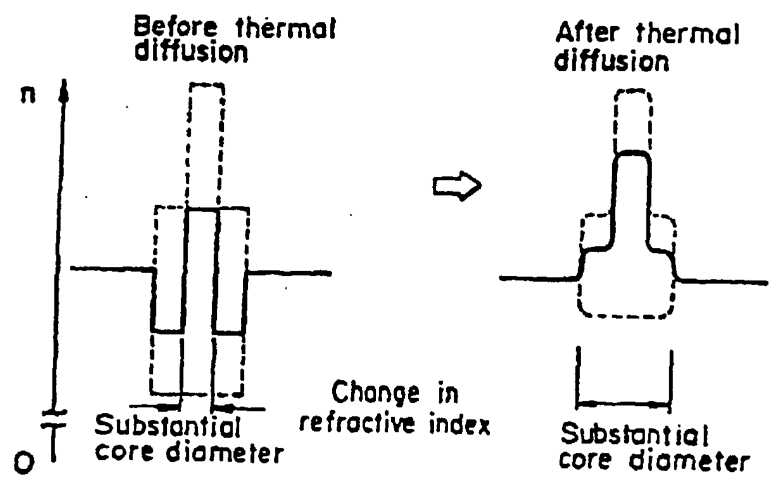


Fig. 8A

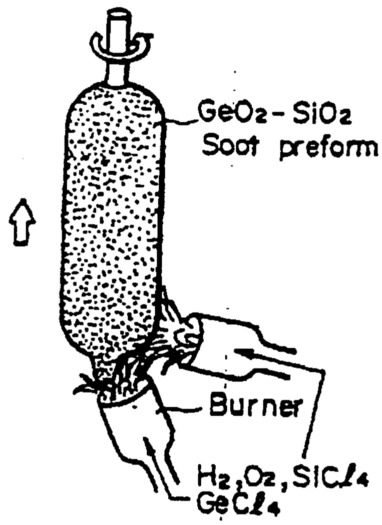


Fig. 8B

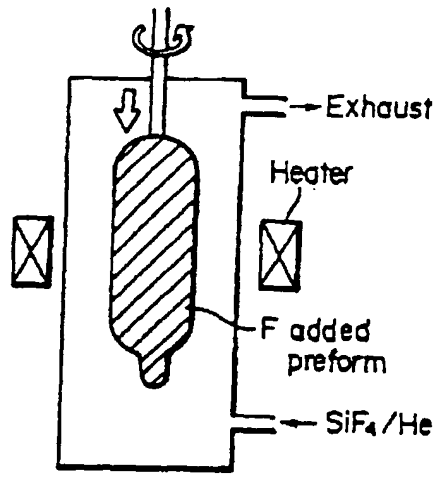


Fig. 8C

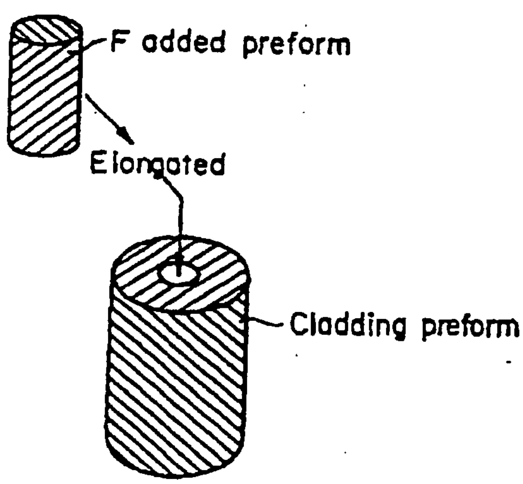
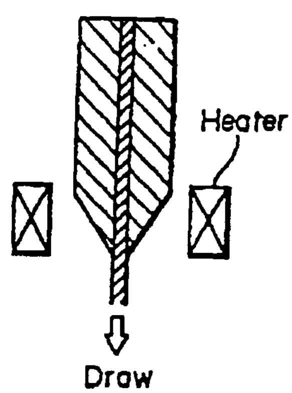


Fig. 8D



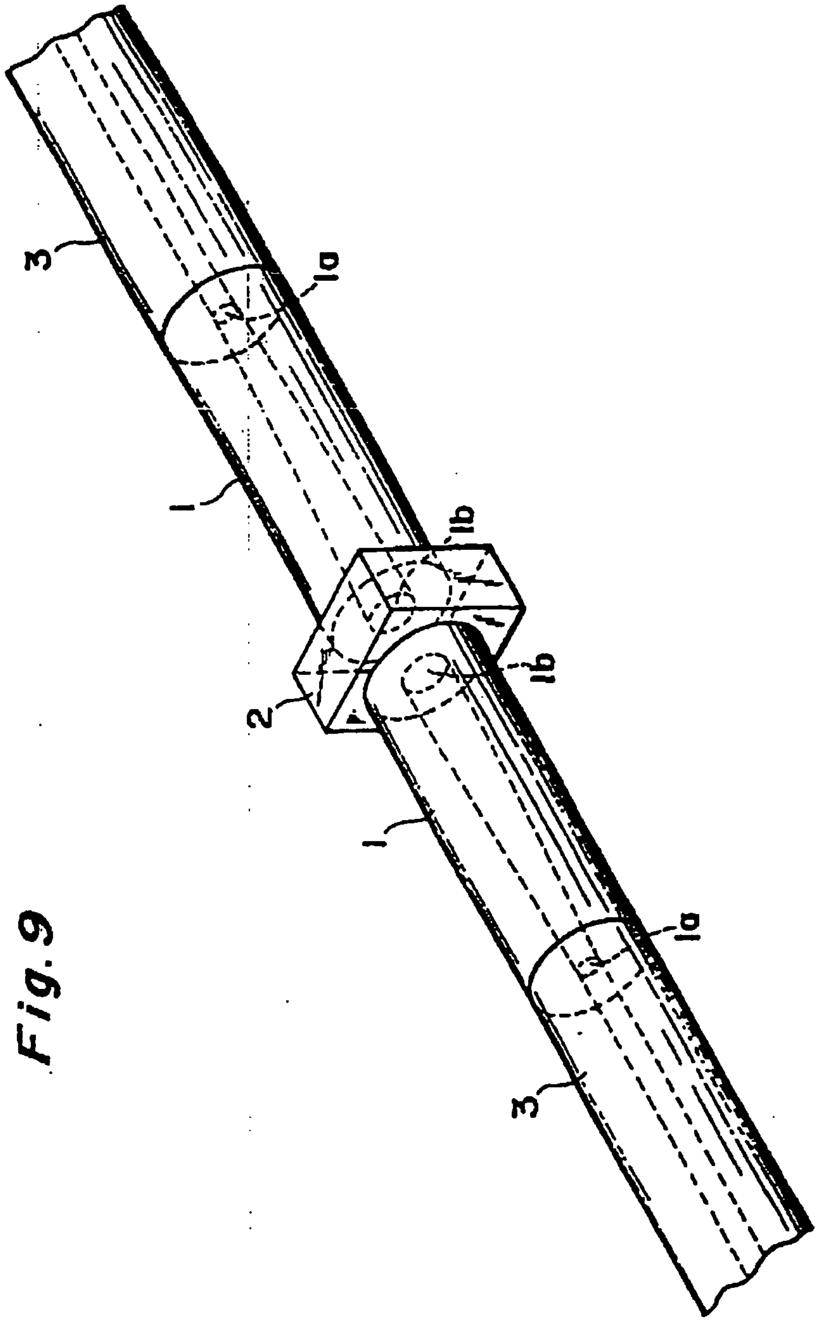


Fig. 9

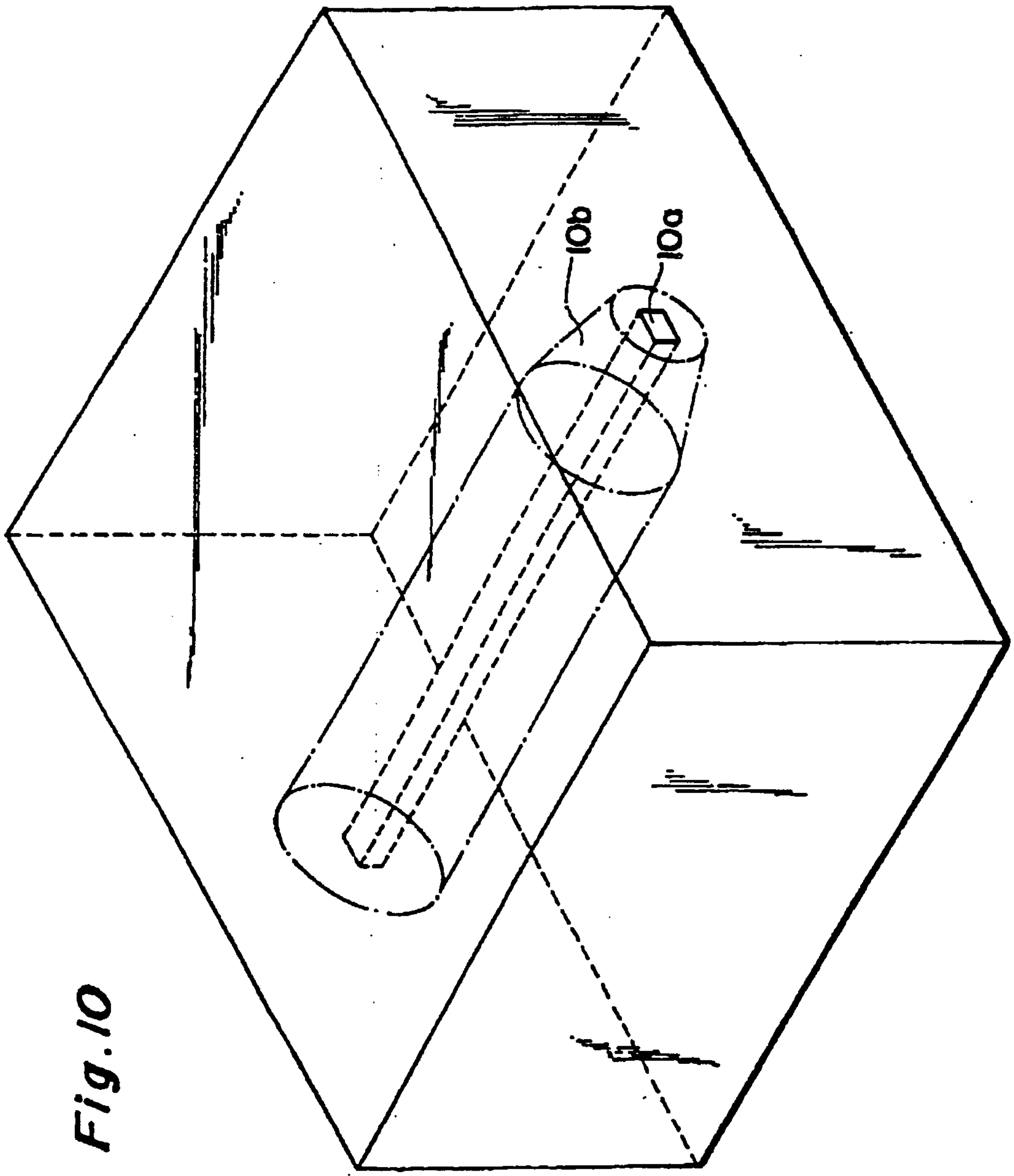


Fig.10